B. N. MANDAL UNIVERSITY MADHEPURA

SYNOPSIS FOR Ph. D. DEGREE IN PHYSICS

FACULTY OF SCIENCE

1. TITLE OF THE RESEARCH

STUDY OF COMPACT DIELECTRIC RESONATOR ANTENNA WITH IMPROVED BANDWIDTH VIA LOADING OF METAL RING

2. WORK PLAN

a. Purpose and Need of the Study

In the era of modern wireless communication, antennas with compact dimensions, high radiation efficiency, and wide impedance bandwidth are in high demand. The continuous evolution of wireless systems — such as 5G, WLAN, radar sensors, and Internet of Things (IoT) — has intensified the need for antennas that can meet the requirements of multi-band and broadband operations without compromising performance.

Among various antenna types, Dielectric Resonator Antennas (DRAs) have emerged as strong candidates because of their low conductor losses, high radiation efficiency, and suitability for high-frequency applications. However, a key drawback of conventional DRAs is their narrow impedance bandwidth, typically resulting from their high-Q resonant nature. This limitation restricts their use in broadband systems.

To address this challenge, various bandwidth-enhancement techniques such as stacking, multiple resonators, using hybrid modes, or modifying feed structures have been studied. In recent years, metallic loading—especially metal-ring loading—has gained attention as an effective and compact solution for bandwidth enhancement without significant size increase[5,6].

The significance of this research lies in developing a simple, cost-effective, and compact antenna structure capable of meeting modern wireless demands. Unlike

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complex multi-resonator or stacked DRAs, the proposed metal-ring-loaded DRA achieves bandwidth enhancement with minimal structural complexity and no increase in antenna volume.

Potential benefits include:

Reduced antenna footprint for portable applications.

Enhanced performance for wideband communication systems.

Applicability across multiple frequency bands (S, C, X, and mmWave).

This approach aligns with current trends toward miniaturized, efficient, and broadband antennas in next-generation communication systems.

This research aims to design and analyze a compact dielectric resonator antenna (DRA) with improved bandwidth achieved through metal-ring loading[1-3]. The proposed structure offers a balance between compactness, wide bandwidth, and efficient radiation performance. The proposed research on a Compact Dielectric Resonator Antenna with Improved Bandwidth via Loading of Metal Ring aims to overcome the long-standing limitation of narrow bandwidth in DRAs. By intelligently introducing a metal ring around the resonator, the impedance bandwidth can be significantly enhanced without increasing the antenna's physical footprint.

This work holds promise for future wireless applications demanding compact, efficient, and broadband antennas. The research will contribute to both theoretical understanding and practical implementation of modern antenna designs, supporting the advancement of 5G, IoT, and emerging millimeter-wave communication systems.

b. <u>Details of the Project with Chapterization</u>

We will present a comprehensive study of DRA –that includes the synthesis of the baseline structure of a cylindrical dielectric resonator mounted on a grounded substrate and excited using a micro strip-fed slot or coaxial probe. A metallic ring (continuous or split) will be introduced either around the DRA base or slightly above the substrate to provide reactive loading.

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The metallic ring perturbs the resonant field, creating two closely spaced resonant modes that merge to form a broadband impedance response. Conventional methods for bandwidth enhancement include the Use of low permittivity materials, Stacking multiple dielectric resonators and Employing parasitic elements or slots. However, these methods either increase complexity, antenna size, or reduce efficiency. Metal-ring loading, on the other hand, can enhance bandwidth with minimal volume increase, easy fabrication, and improved impedance matching. The integration of a metallic ring around or near the DRA perturbs the field distribution and introduces additional resonant modes. The interaction between the DRA's intrinsic mode and the metal ring's induced current leads to multi-mode or hybrid resonances, resulting in an extended impedance bandwidth. This approach provides a compact, simple, and cost-effective solution suitable for modern compact devices.

The proposed research will focus on the following main objectives:

i. To design a compact DRA using high-permittivity dielectric material suitable for operation in microwave or millimeter-wave frequency bands.

ii. To investigate the effect of metallic ring loading on the impedance bandwidth, resonant modes, and radiation characteristics of the DRA.

iii. To optimize the metal-ring dimensions and placement (inner radius, width, and gap) for maximum bandwidth enhancement while maintaining high gain and efficiency.

iv. To compare the performance of the proposed metal-ring loaded DRA with a conventional unloaded DRA.

The scientific investigation of the project will be made under the following heads:-

1. Introduction
2. Review of literature
3. Materials and methods
4. Discussion
5. Summary and conclusion
6. Biography/References

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c. Methodology

The present research aims to design, simulate, fabricate, and analyze a compact dielectric resonator antenna (DRA) with enhanced bandwidth through metal ring loading. The methodology is systematically structured into sequential stages, ensuring accurate design development, optimization, and experimental validation.

The study begins with an extensive literature review on existing bandwidth enhancement techniques for dielectric resonator antennas, including hybrid modes, parasitic elements, stacked configurations, and various loading mechanisms. This review helps identify limitations such as increased size, complexity, or radiation distortion in earlier designs. Based on these findings, the concept of metallic ring loading is chosen for its potential to improve impedance bandwidth while maintaining compactness and stable radiation characteristics.

In the design phase, an appropriate dielectric material with moderate to high permittivity and low loss tangent is selected to achieve miniaturization and high efficiency. A cylindrical DRA geometry is preferred for its simple structure and ease of excitation. A metallic ring is then introduced around or near the DRA surface. This ring acts as a coupling structure that perturbs the electromagnetic fields, excites additional resonant modes, and thus enhances the impedance bandwidth. The design parameters of the ring—radius, thickness, gap, and position—are treated as optimization variables.

The simulation and optimization are performed using full-wave electromagnetic simulation tools such as CST Microwave Studio or HFSS. The baseline DRA (without the ring) is first analyzed to determine its resonant frequency, return loss (S_{11}), gain, and radiation pattern. Subsequently, the metal ring is added, and parametric studies are conducted by varying one parameter at a time to understand its effect on the antenna's bandwidth and impedance matching. The goal is to maximize the fractional bandwidth while maintaining stable radiation patterns and reasonable gain.

Finally, the proposed DRA's performance is compared with a conventional DRA of similar dimensions to highlight improvements in bandwidth and efficiency. The findings are discussed in terms of the physical mechanism—mode coupling,

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reduced quality factor (Q), and enhanced radiation conductance caused by the metal ring.

The study concludes with suggestions for further improvement, such as multi-ring structures, stacked DRAs, or metamaterial integration, to achieve even wider bandwidth suitable for modern wireless and radar applications.

d. References

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I testify that I am in a position to devote time for this research work and undertake to complete this research work within specified maximum time limit.

Bhaggashree 25/11/25

Full signature of the research scholar

with date.

The candidate has undertaken to complete the research work under my supervision and guidance under the time limit.

25/11/25

Full signature of the supervisor

with date designation and address .

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